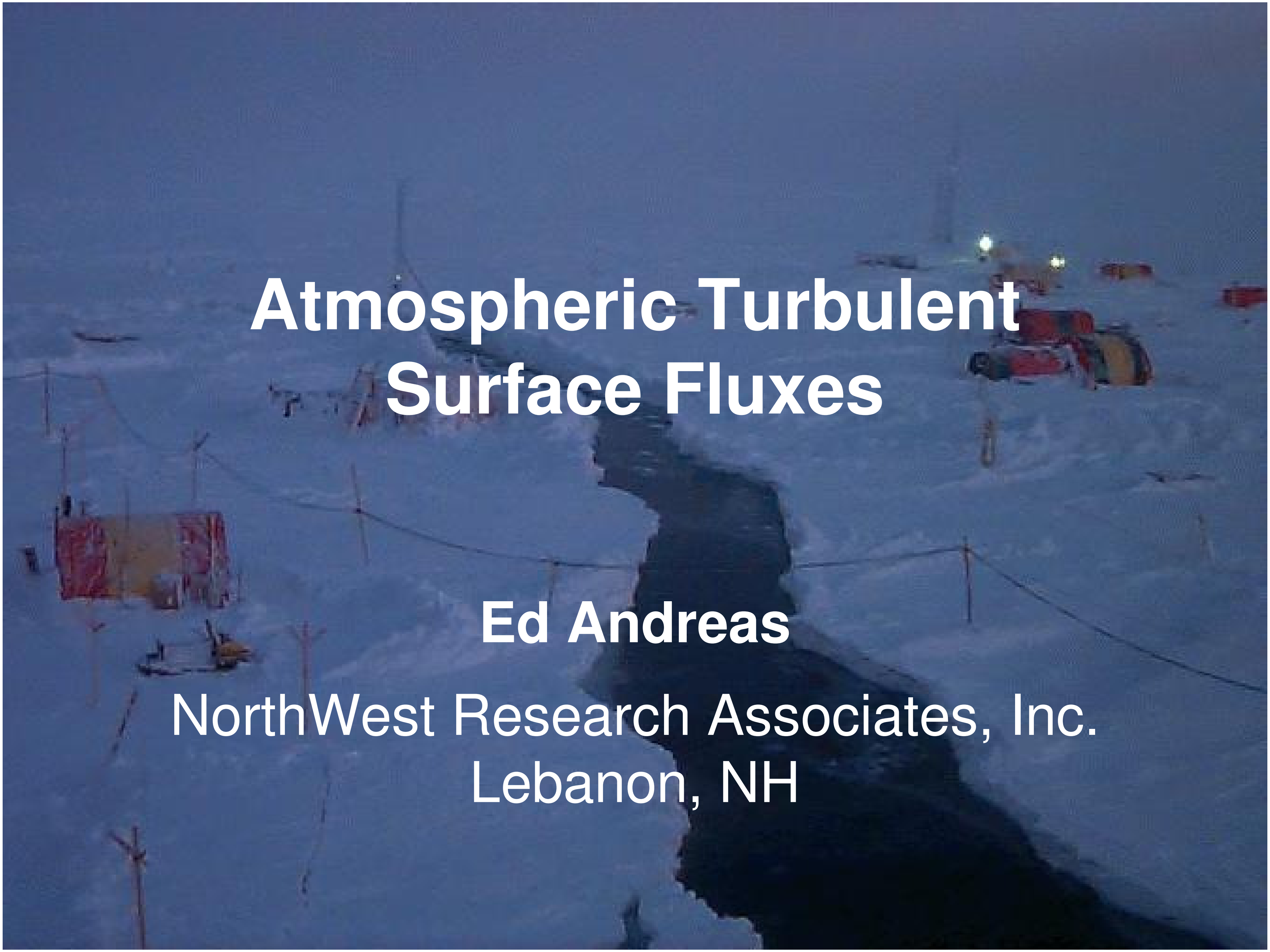

Atmospheric Turbulent Surface Fluxes

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Parameterize Turbulent Surface Flux

Momentum Flux:

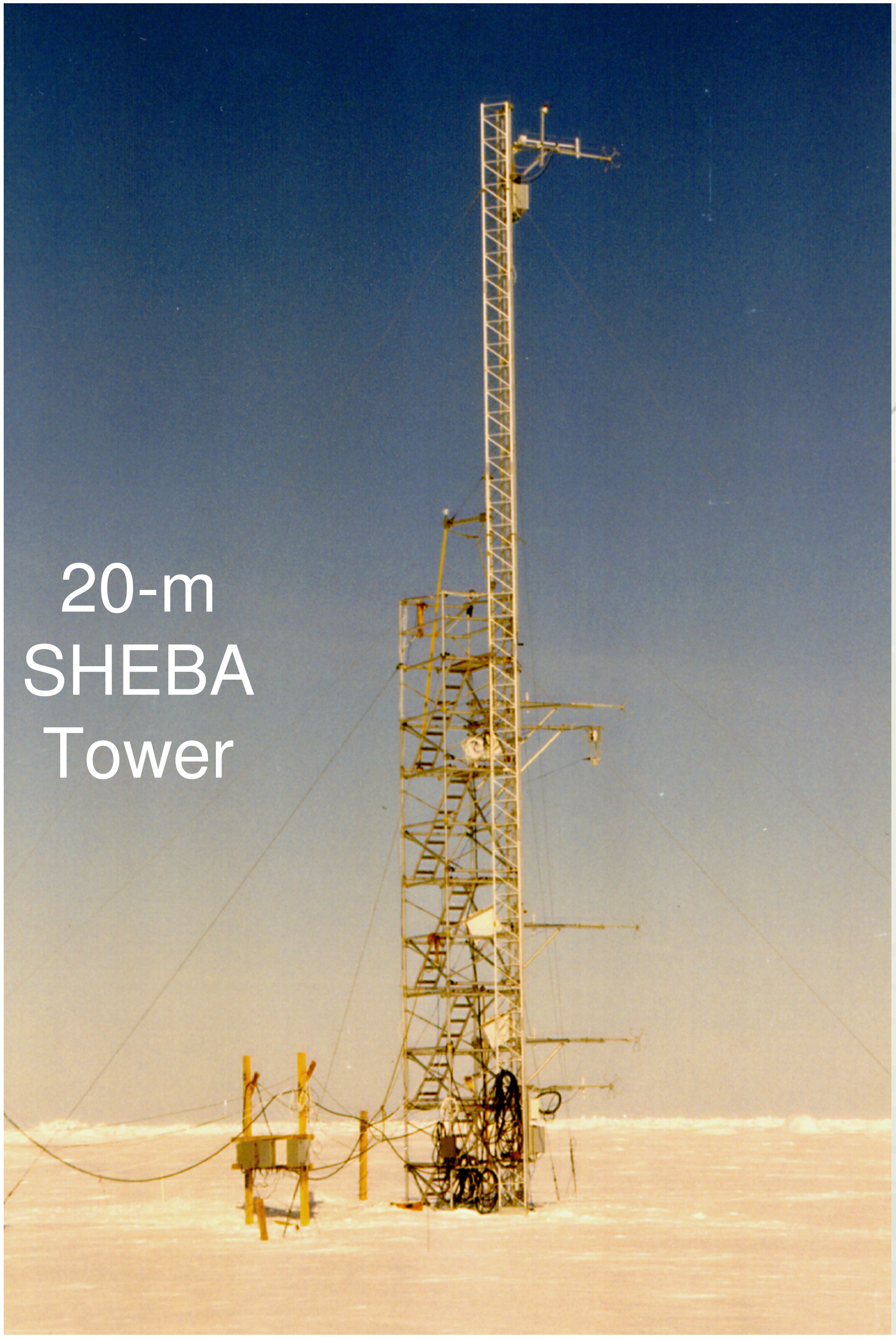
$$\tau \equiv -\rho \overline{uw} = \rho u_*^2 = \rho C_{Dr} S_r^2$$

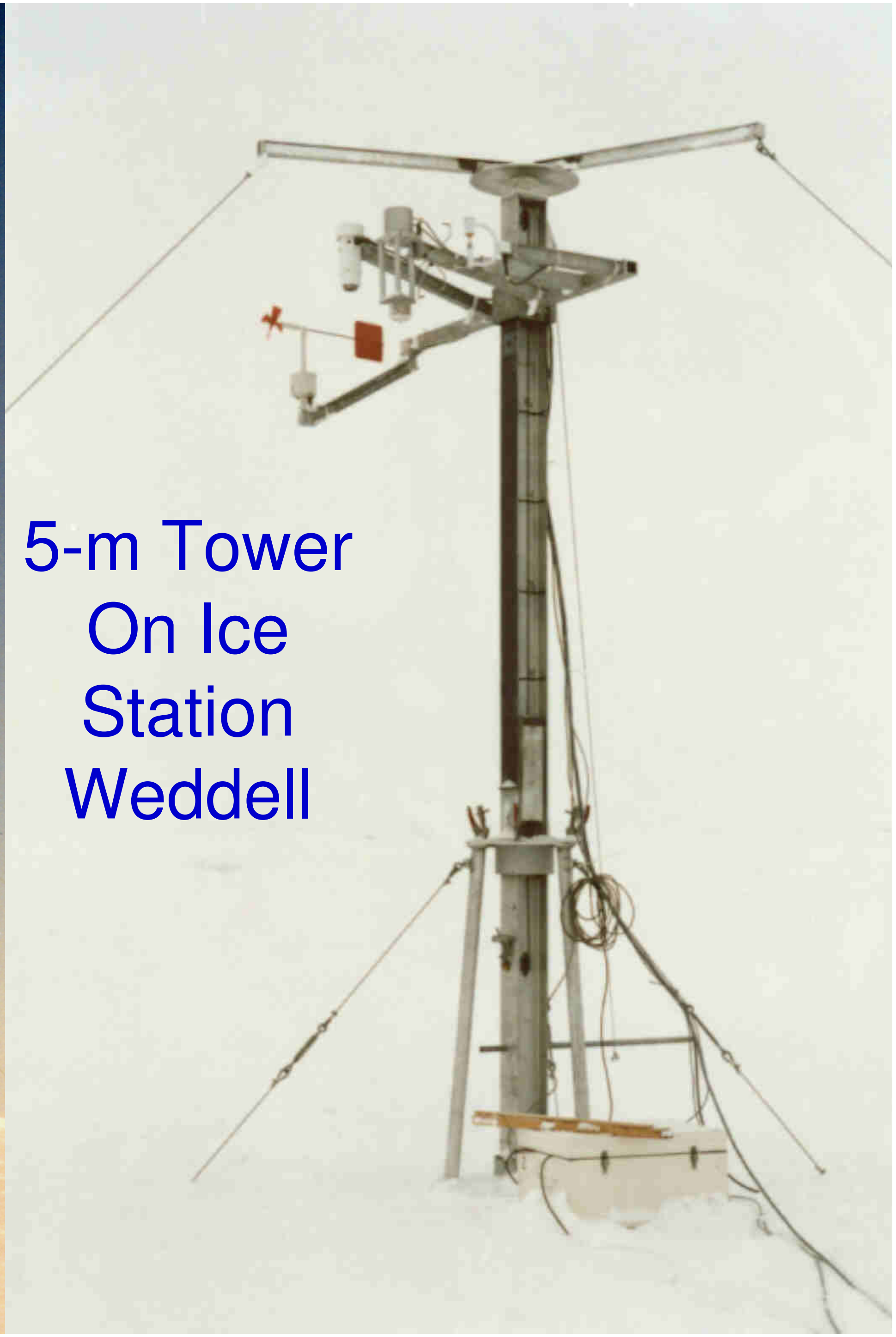
Sensible Heat Flux:

$$H_s \equiv \rho c_p \overline{wt} = \rho c_p C_{Hr} S_r \left(T_s - T_r\right)$$

Latent Heat Flux:

$$H_L \equiv \rho L_v \overline{wq} = \rho L_v C_{Er} S_r \left(Q_s - Q_r\right)$$


20-m
SHEBA
Tower


5-m Tower
On Ice
Station
Weddell

Drag Coefficient

$$C_{Dr} = \frac{k^2}{\left[\ln(r/z_0) - \psi_m(r/L)\right]^2}$$

where k is the von Kármán constant, r is an arbitrary reference height, z_0 is the roughness length for momentum, L is the Obukhov length, and ψ_m is a stability correction

Scalar Transfer Coefficients

For Sensible Heat:

$$C_{Hr} = \frac{k^2}{\left[\ln\left(\frac{r}{z_0}\right) - \psi_m\left(\frac{r}{L}\right)\right]\left[\ln\left(\frac{r}{z_T}\right) - \psi_h\left(\frac{r}{L}\right)\right]}$$

For Latent Heat:

$$C_{Er} = \frac{k^2}{\left[\ln\left(\frac{r}{z_0}\right) - \psi_m\left(\frac{r}{L}\right)\right]\left[\ln\left(\frac{r}{z_Q}\right) - \psi_h\left(\frac{r}{L}\right)\right]}$$

Drag Coefficient: 10m, Neutral

In neutral stratification, at a standard reference height of 10 m,

$$C_{DN10} = \frac{k^2}{\left[\ln\left(10/z_0\right)\right]^2}$$

where

$$z_0 = r\exp\left\{-\left[k\,C_{Dr}^{-1/2} + \psi_m\left(r/L\right)\right]\right\}$$

Scalar Transfer Coefficients: Neutral

In neutral stratification, at a standard reference height of 10 m, the scalar transfer coefficients are

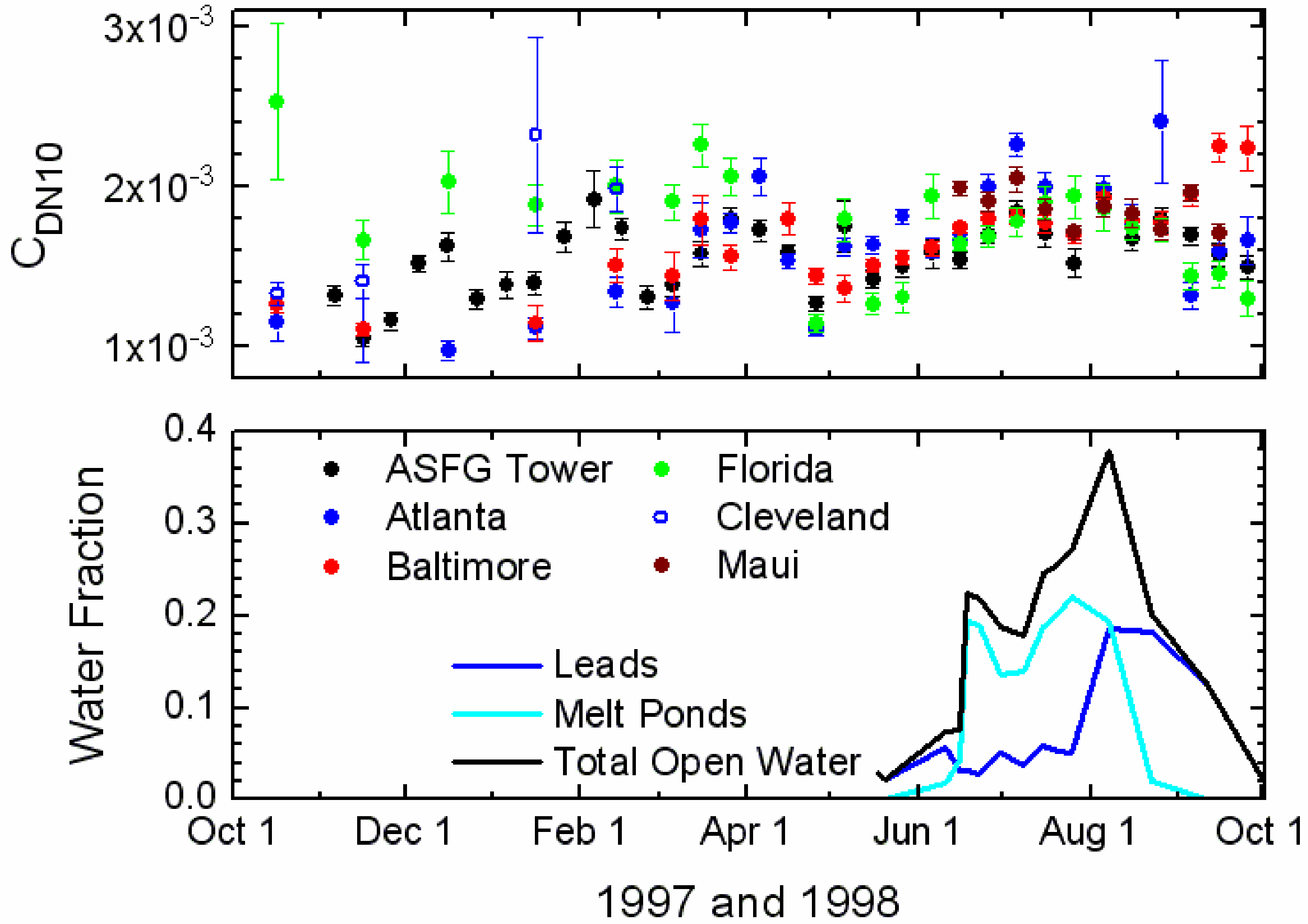
$$C_{sN10} = \frac{k^2}{\left[\ln\left(10/z_0\right)\right]\left[\ln\left(10/z_s\right)\right]} = \frac{k\,C_{DN10}^{1/2}}{\ln\left(10/z_s\right)}$$

where

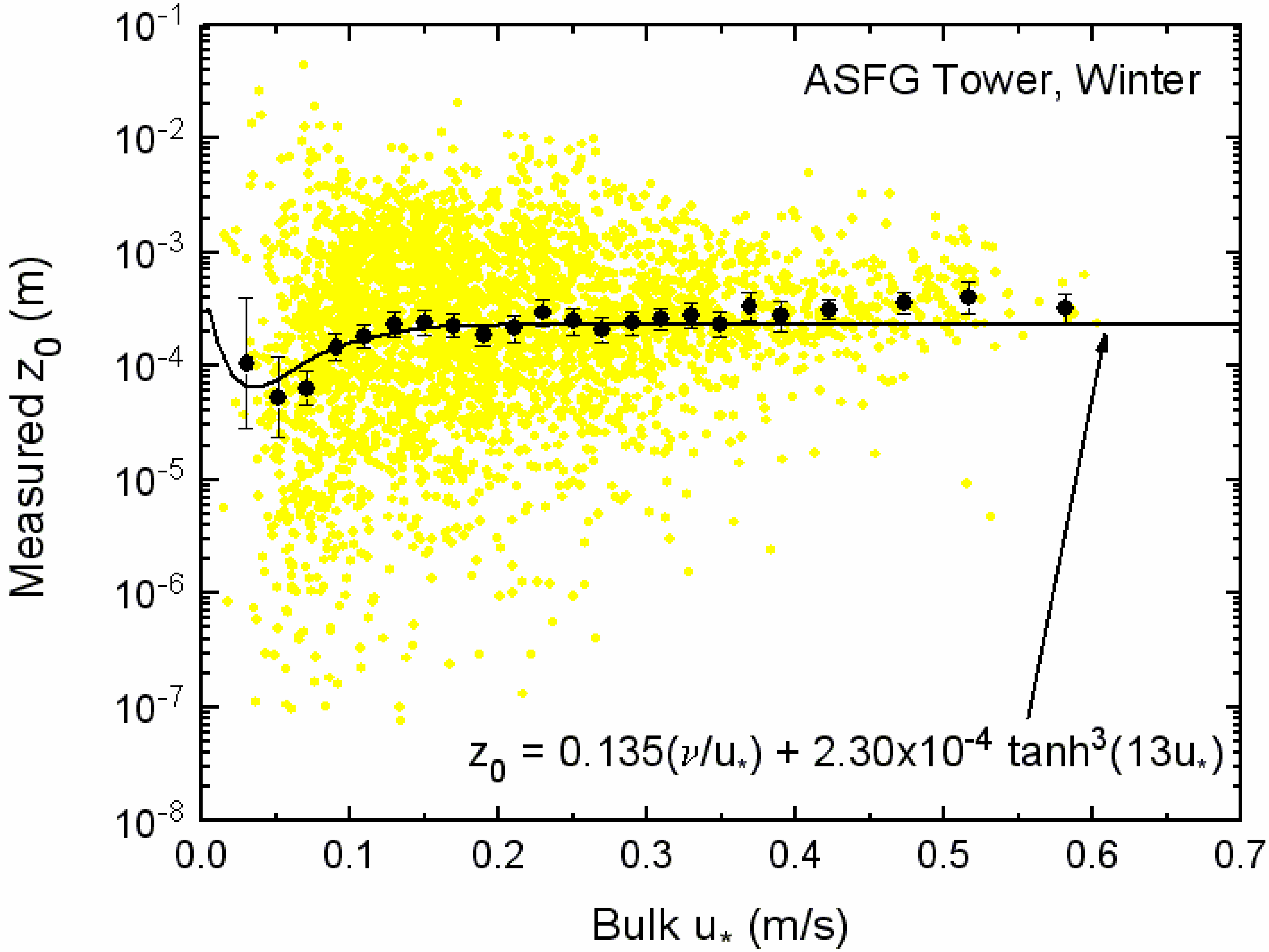
$$z_s = r\exp\left\{-\left[k\,C_{Dr}^{1/2}\,C_{sr}^{-1} + \psi_h\left(r/L\right)\right]\right\}$$

SHEBA Flux-PAM Site Atlanta

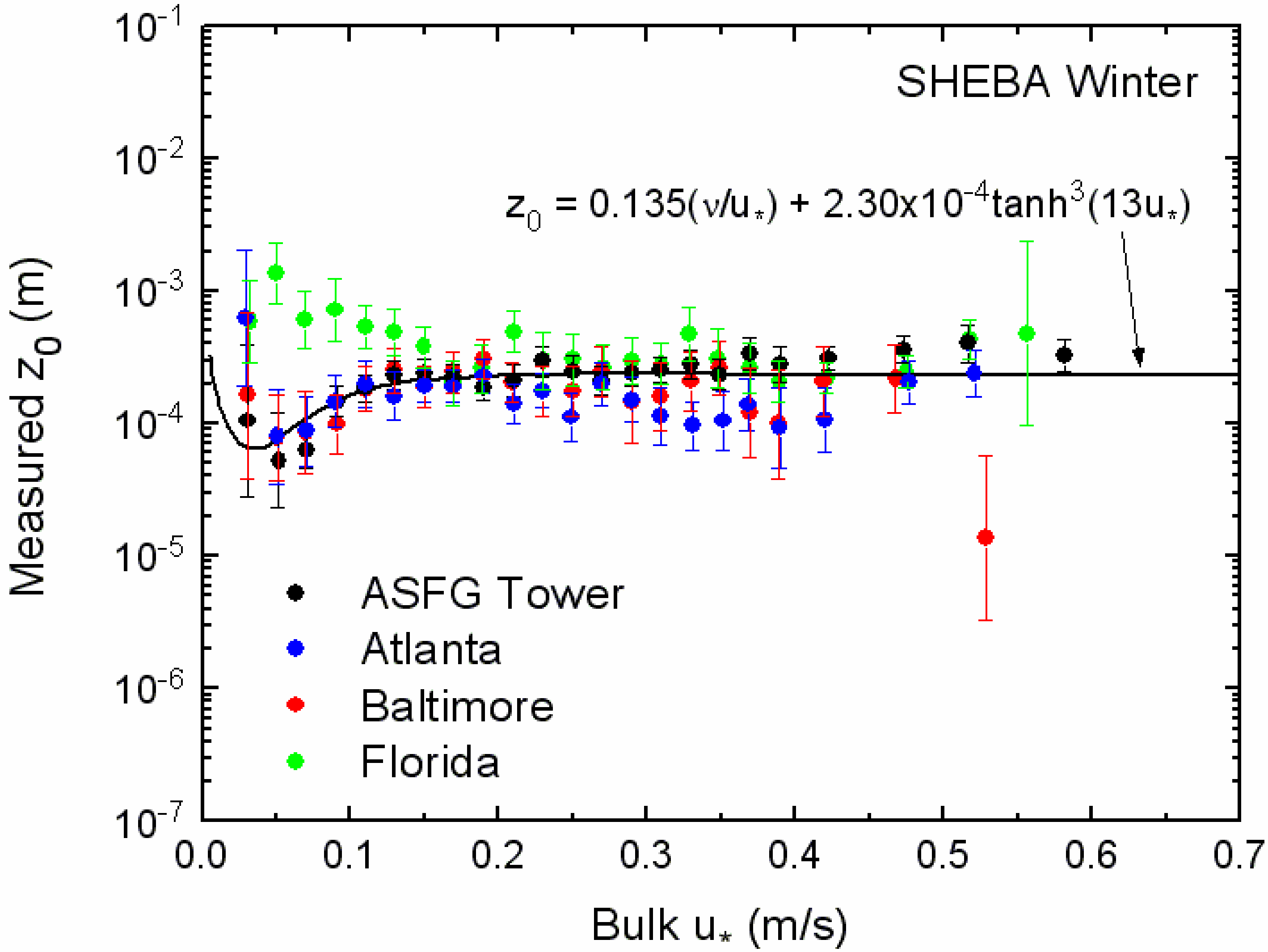
SHEBA Time Series



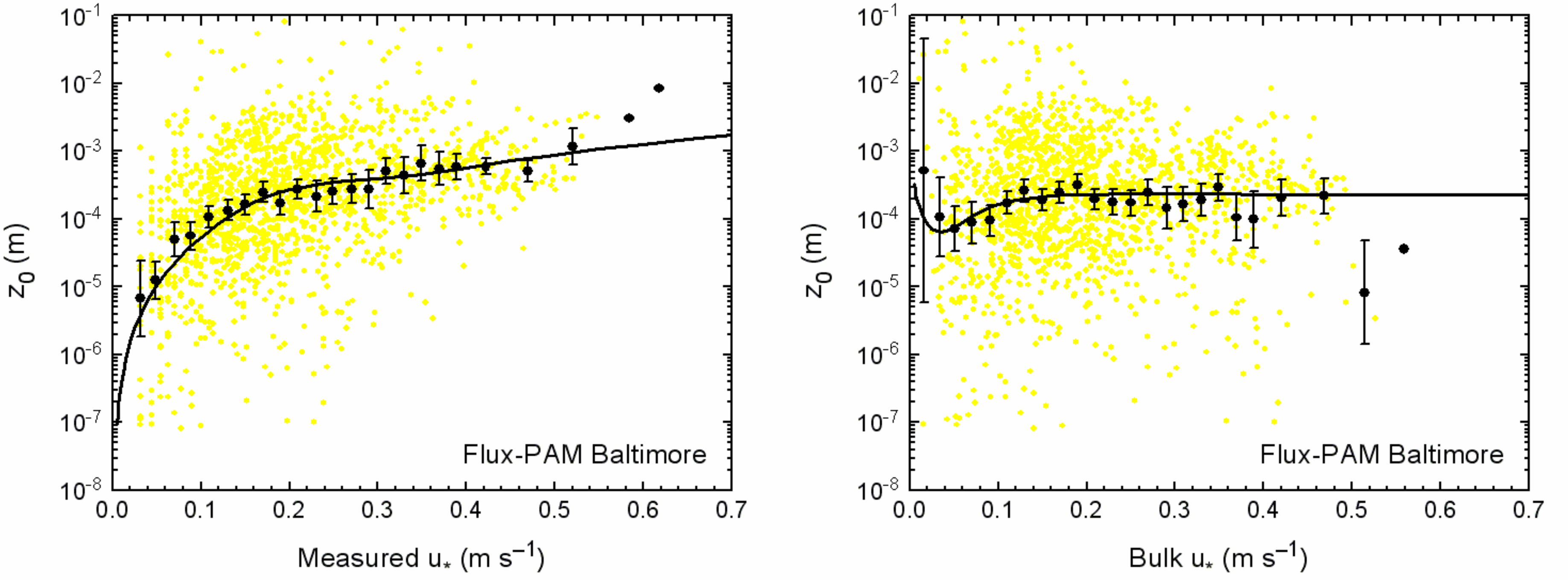
SHEBA Summer, 7/27/98



ASFG Tower, Winter
$z_0 = 0.135(\nu/u_*) + 2.30\times10^{-4}\,\tanh^3(13u_*)$
Measured z_0 (m)
Bulk u_* (m/s)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

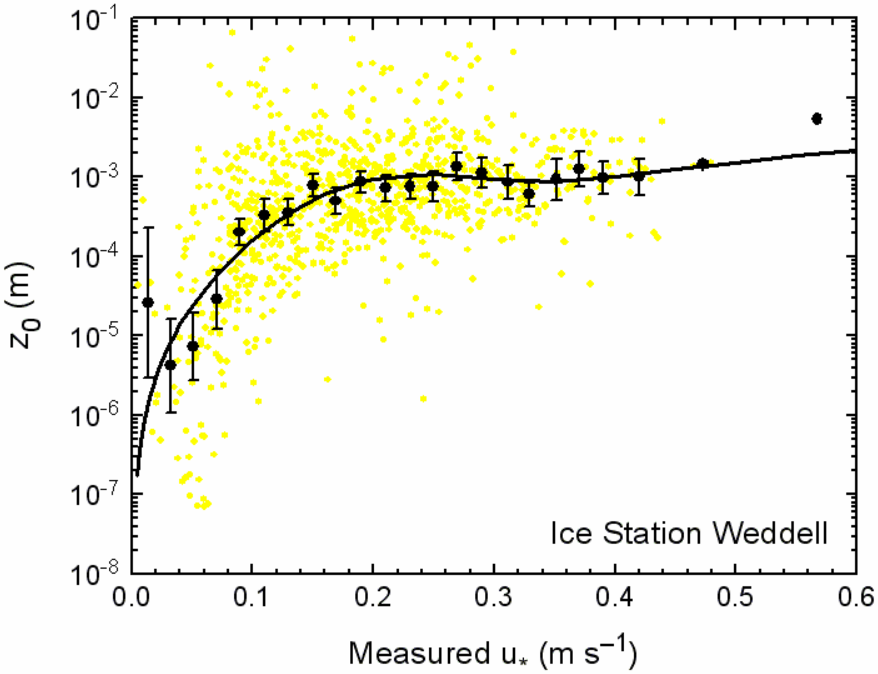

SHEBA Winter
z0 = 0.135(ν/u*) + 2.30x10-4tanh3(13u*)
ASFG Tower
Atlanta
Baltimore
Florida
Measured z0 (m)
Bulk u* (m/s)
10-1
10-2
10-3
10-4
10-5
10-6
10-7
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

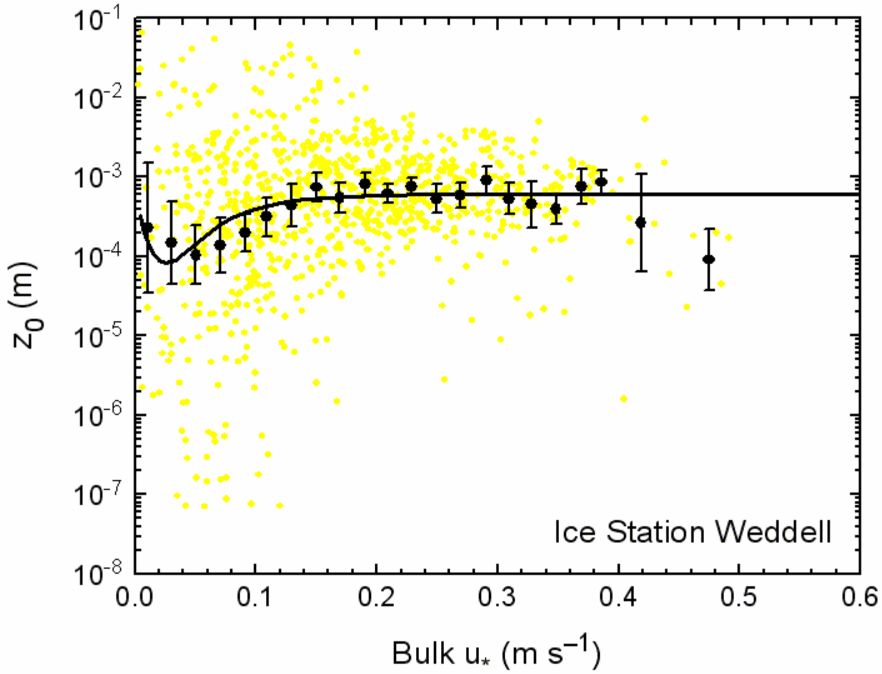
Effect of Fictitious Correlation



Example from SHEBA

Effect of Fictitious Correlation, #2





Example from Ice Station Weddell

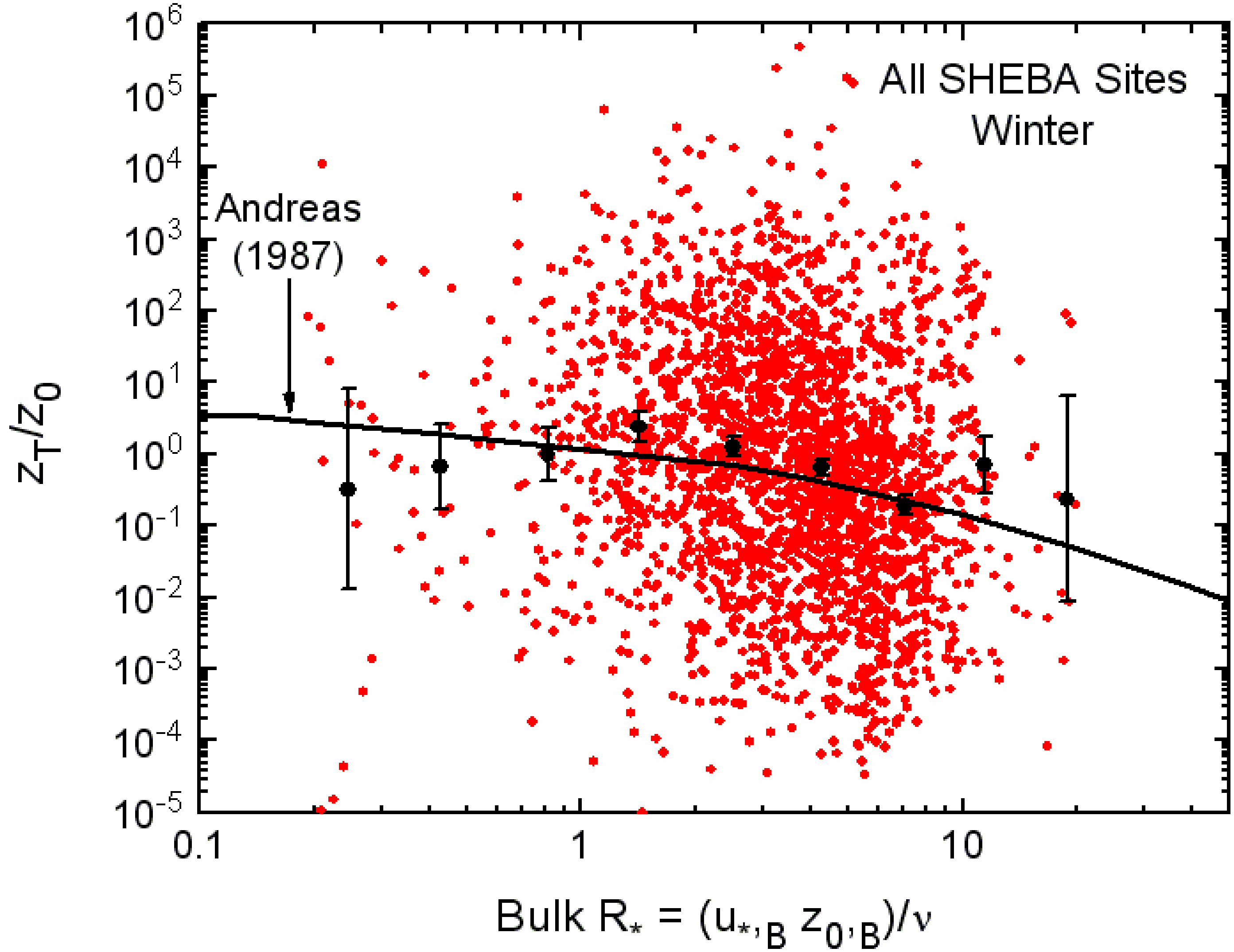
Why the Fictitious Correlation?

In plots of measured z_0 versus measured u_*, z_0 comes from

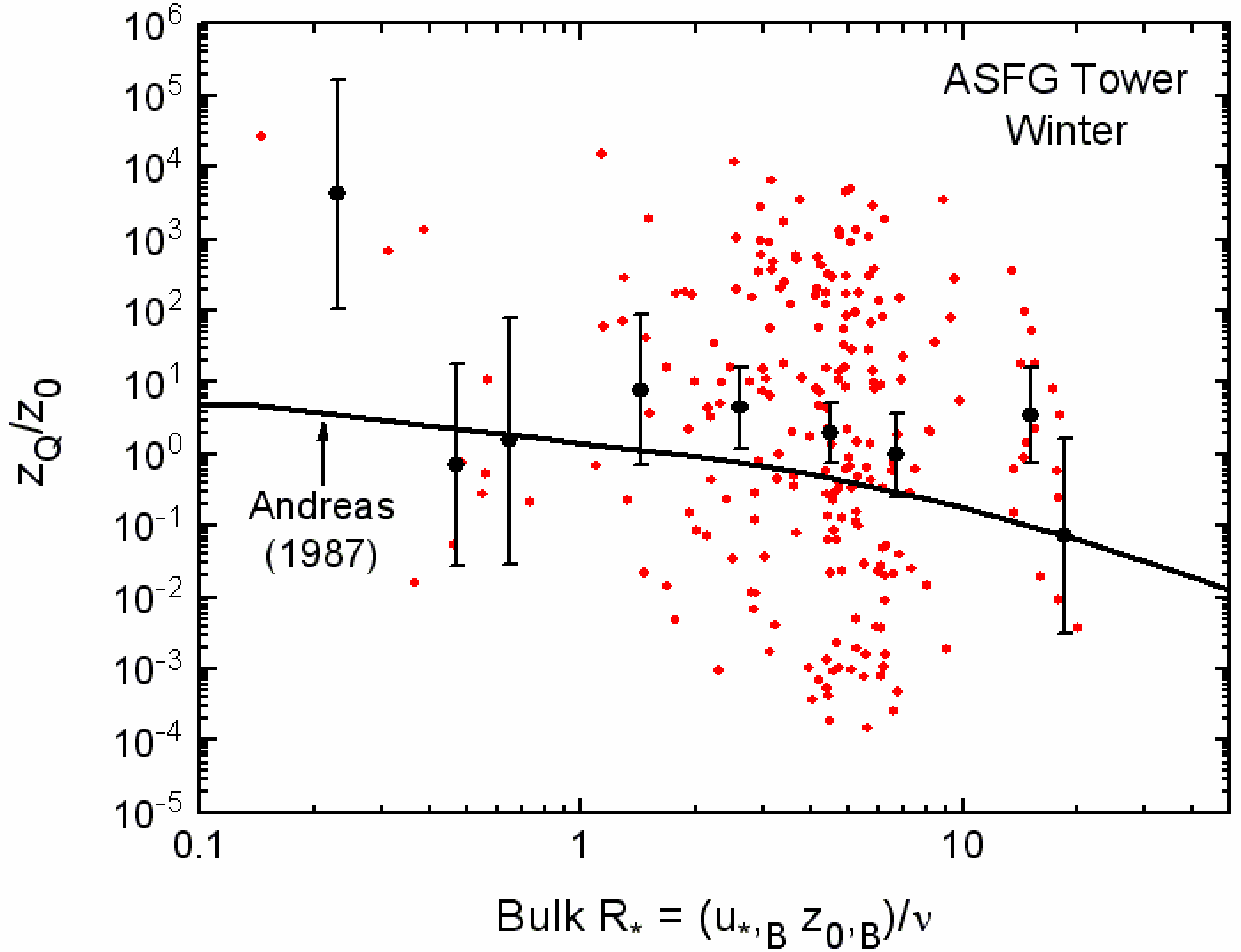
$$z_0 = r \exp\left\{-\left[\frac{k S_r}{u_*} + \psi_m(r/L)\right]\right\}$$

where also

$$\frac{r}{L} = -\frac{k\, g\, r}{T\, u_*^3}\left(\frac{H_s}{\rho c_p} + \frac{0.61T}{1 + 0.61Q}\frac{H_L}{\rho L_v}\right)$$

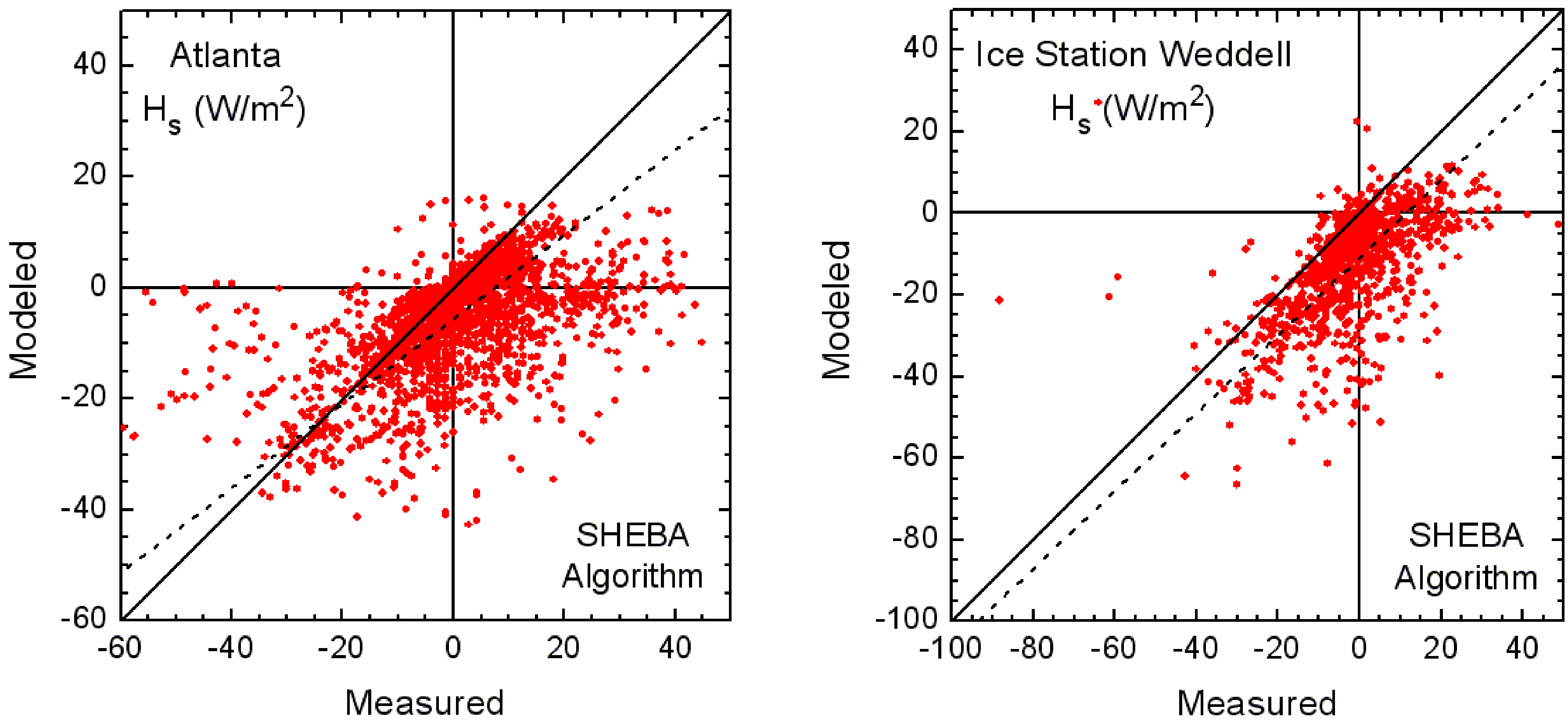


All SHEBA Sites
Winter
Andreas
(1987)
z_T/z_0
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0.1
1
10
Bulk $R_* = (u_{*,B}\, z_{0,B})/\nu$

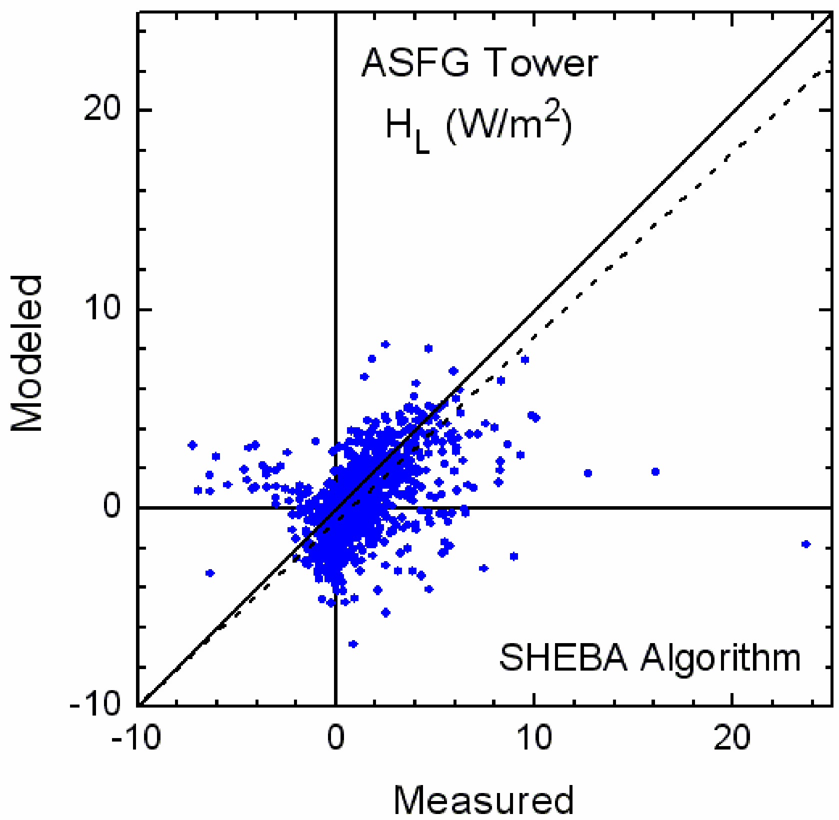


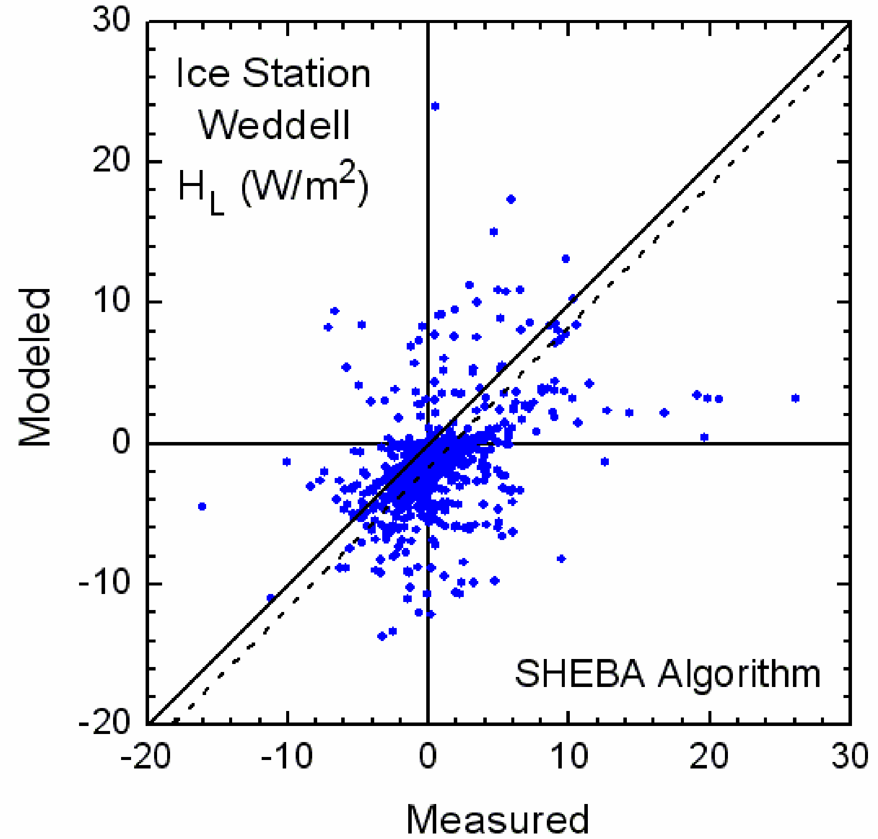
ASFG Tower
Winter
Andreas
(1987)
z_Q/z_0
10^{6}
10^{5}
10^{4}
10^{3}
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
0.1
1
10
Bulk $R_* = (u_{*,B}\ z_{0,B})/\nu$

Sensible Heat Flux

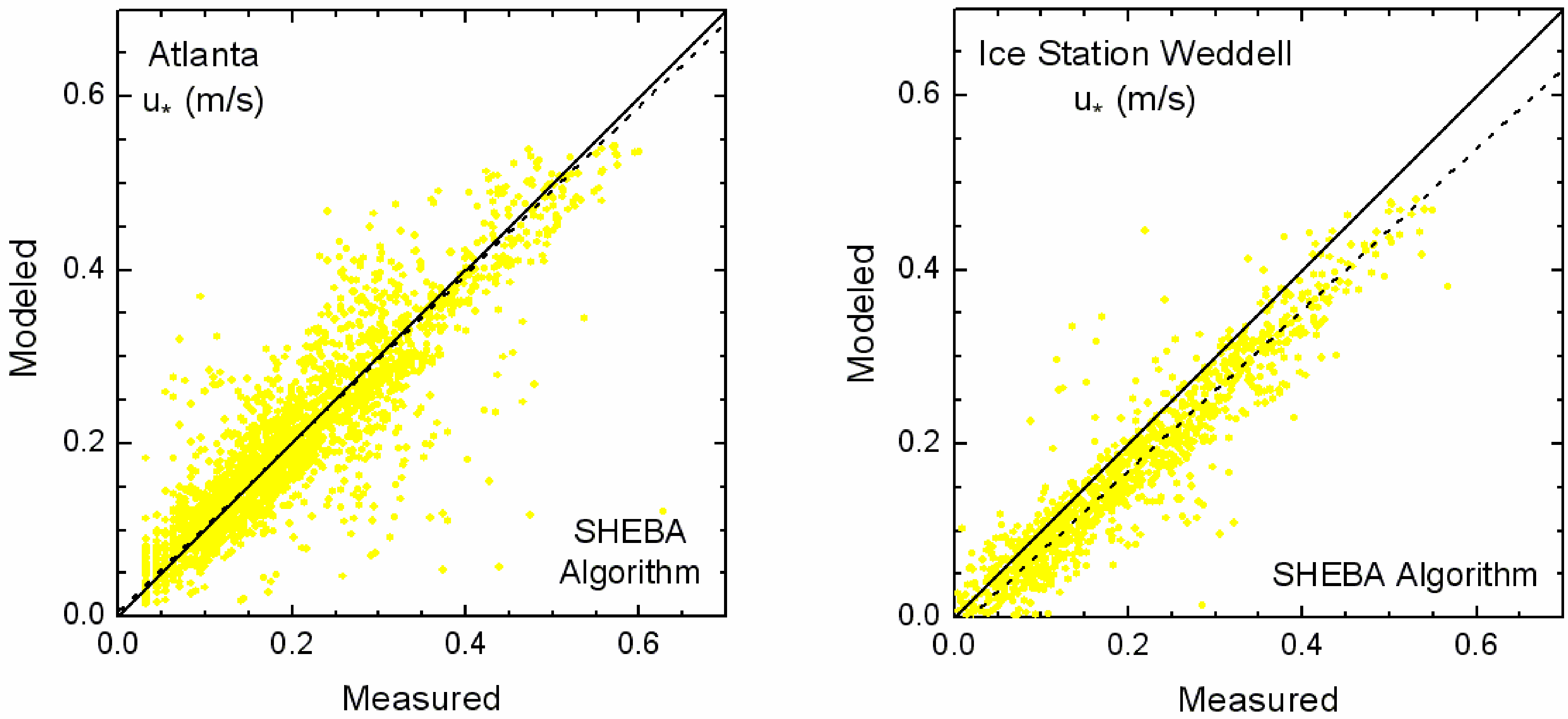


Latent Heat Flux

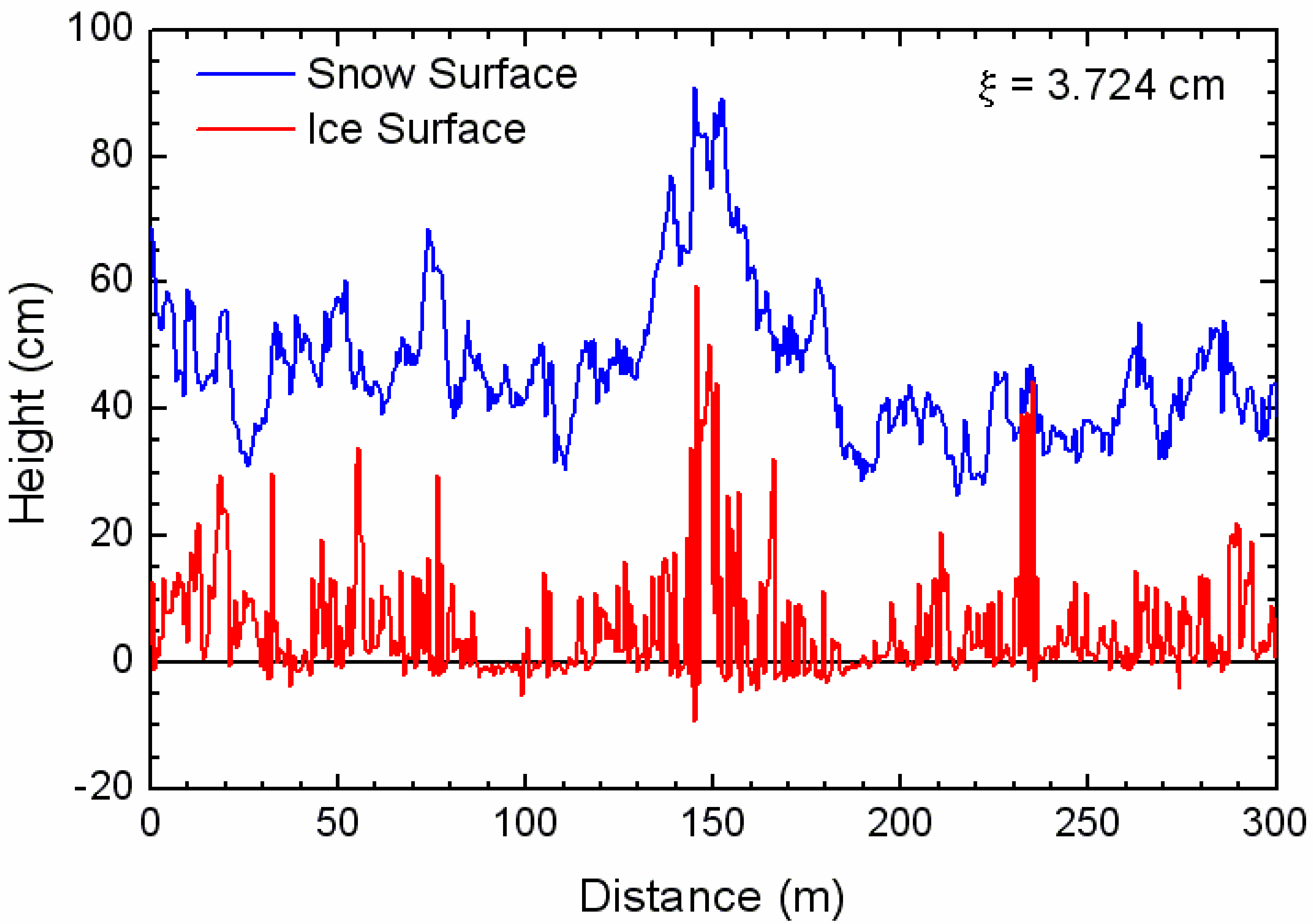




Friction Velocity



Surface Profile on Ice Station Weddell



Quantify Physical Roughness

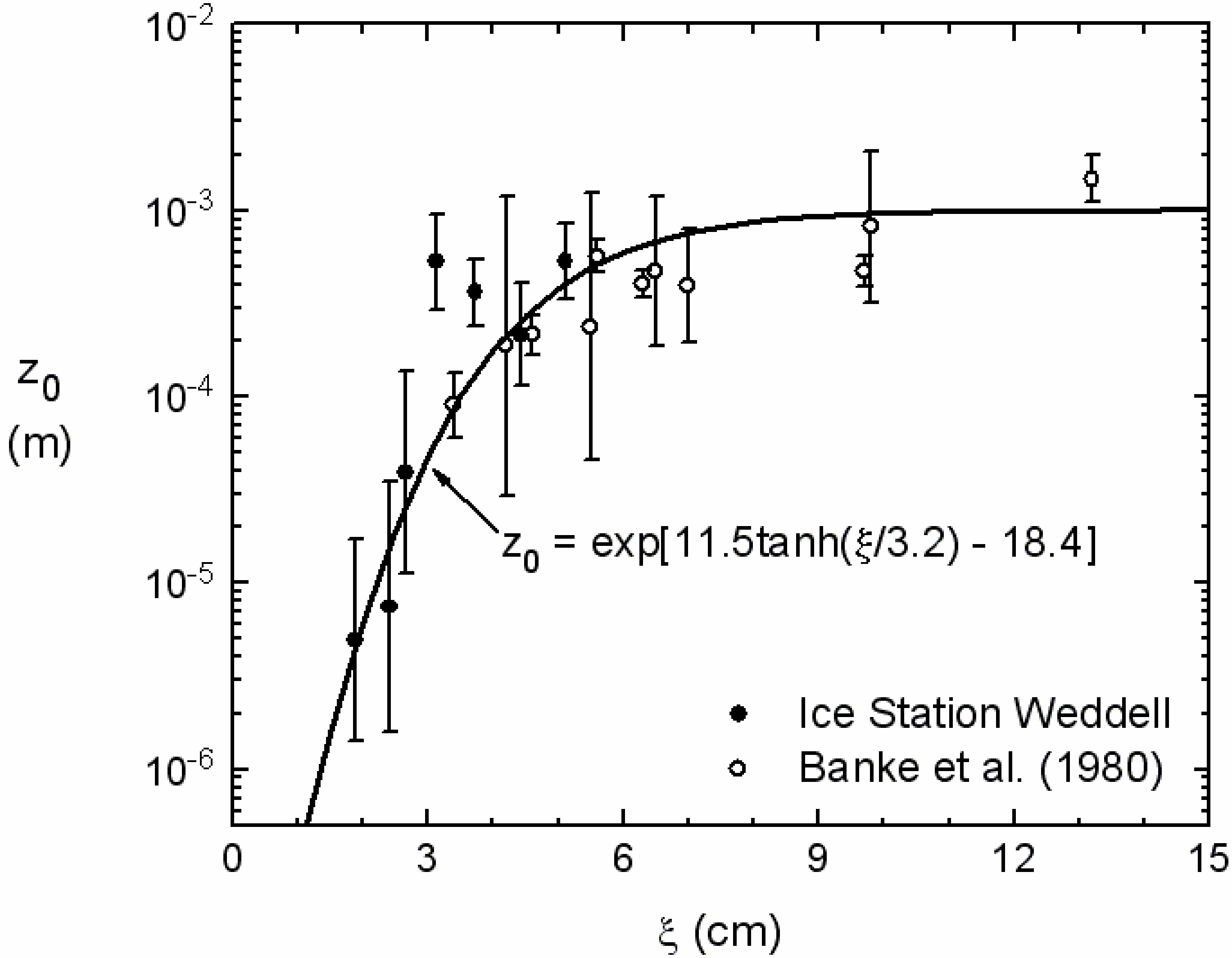
A roughness parameter related to the surface variance (from Banke et al. 1980)

$$\xi^2 = \int_{\kappa_0}^{\infty} \Phi(\kappa)\, d\kappa$$

where κ is the wavenumber, and $\Phi(\kappa)$ is the wavenumber spectrum of the surface elevation

κ_0 is a cutoff wavenumber of 0.5 rad m^{-1} (equivalent to a maximum wavelength of 12.6 m)

Compare Physical and Aerodynamic Roughness



What a Turbulent Flux Algorithm Does

- It’s a “Flux Coupler.”
- It provides estimates of the surface fluxes of momentum and sensible and latent heat from measured or modeled meteorological quantities (wind speed, surface temperature, air temperature, humidity).
- It provides the lower flux boundary conditions for the atmosphere.
- It provides the upper flux boundary conditions for the ice or ocean.

Dramatic pause . . .

Discussion, Topic 1

Does anyone besides turbulence aficionados like me really care about the turbulent surface fluxes over sea ice?

Discussion, Topic 2

What accuracy should we strive for in measuring, parameterizing, and modeling the surface fluxes (including now the radiative fluxes)?

For example, the TOGA COARE program (tropical Pacific Ocean) aimed for an uncertainty of $\pm 10\ \mathrm{W\ m^{-2}}$ in the surface energy budget.

Discussion, Topic 3

Do we know enough yet and would there be any value in compiling gridded datasets of surface fluxes for the Arctic and Antarctic sea ice regions, as is being done over the global wet ocean?

A catch is that the ocean sets benefit from buoys, ships of opportunity, and satellite-derived surface winds.